Clinical Applications of Computerized Algorithms

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I've become involved in the process of computerizing algorithms about the pharmacologic treatment of psychiatric patients. This experience focused my attention on the challenge to create computerized algorithms that will have maximum positive impact on the care of patients. I will discuss several aspects of this challenge: What is it that makes someone an expert? What are the common cognitive errors of people making decisions? What are the advantages of algorithms and especially computerized algorithms? What needs to be done to make computerized algorithms widely used? And, What are the prospects for refining algorithms through user feedback - probably on the Internet?

Studies of Decision Making as a Cognitive Process

There is a large and very interesting research literature about how people make decisions "under uncertainty" as its called - that is decision making under typical clinical conditions where information about the patient is incomplete, and scientific knowledge is also limited and usually does not apply exactly to the specific case at hand (Kahneman et al 1982, Dowie and Elstein, 1988, Williams, 1982).

What Makes Someone an Expert? How does an expert solve a problem differently from a novice? It appears that experts do not use more pieces of information about a case than novices but they have much more knowledge about which factors are important in a particular situation. In addition to knowing which facts are important, they have greater knowledge about how much weight to give to each relevant fact. In a few moments we will, however, examine how even experts are not as good at combining those weighted factors to reach a decision as they are at recognizing which factors are important.

Seeing large numbers of very similar cases gives experts the opportunity to improve their skills by learning the probabilities of various outcomes and their dependency on particular situations. We will address later how ordinary clinicians may together achieve this advantage now only available to experts.

"He claims to be a specialist, but I think he just has a one-track mind."

Thinking of a typical clinical situation can affirm these research insights: Suppose you decide to ask a gastroenterologist about the symptoms of one of your patients. In anticipation of talking to the gastroenterologist, you might ask the patient quite a few questions about his symptoms - because you don't know which answers are going to be important. When you go to the gastroenterologist, he or she asks questions to learn about the patient's general situation, then often asks a small number of questions about the specific problem before giving you an opinion. The expert's skill lies in knowing how to assess the context of the problem and then the weight to place on certain facts.

Experts know how to break down complex problems into sequences of smaller problems. Each small problem requires only a few facts to resolve it. Experts approach complex problems this way because human information processing is relatively slow, our short-term memory has limited capacity and we are subject to frequent interruptions which would require time consuming rebuilding of mental images if problems were large (Moskowitz, 1988, Payne et al, 1992).

Incremental solutions thus avoid some of our major cognitive shortcomings. However, incremental problem solving is vulnerable to certain kinds of errors: The order of solving sub-problems may affect the outcome. Another problem is that each sub-problem is resolved with a single answer but there may be substantial uncertainty about the correctness of the answer. The answer will be used as the input for the next sub-problem but we are not able to carry forward a good representation of the degree of uncertainty and especially we have trouble manipulating compound probabilities. After 3, 4 or 5 such sub-problems we may be quite lost about the overall probability of the final outcome.
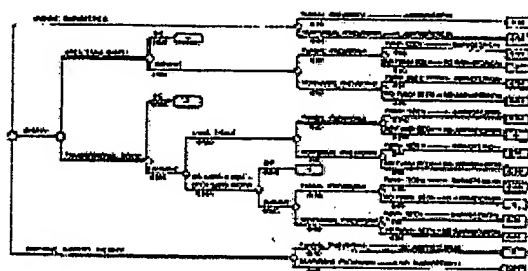

Figure 1 Decision tree for determining best treatment method for male patient with preleukemia and granulocytopenia. From Moskowitz et al.

Figure 1 shows a decision analysis for a patient who has preleukemia and granulocytopenia. A decision

tree like this analyses the steps and assigns objective probabilities to each alternative. The goal is to determine the treatment plan which gives the patient the greatest likelihood of survival. Moskowitz et al analyzed the thinking of three pulmonologists who were asked to recommend treatment in this situation. They all recommended the biopsy path and they dismissed the empiric therapy path as unacceptable. The decision analysis reveals that the empiric therapy would have given the patient as good a chance of survival as the experts' choice. Empiric therapy would have subjected the patient to less procedures and surely have cost less. This figure emphasizes that experts find it difficult to assess the compound probability of alternative paths.

Common Cognitive Errors in Decision Making Here we will add brief descriptions of several other cognitive difficulties found when people make decisions (Dawes, 1988). Experts may be somewhat less prone to these errors but at best they are only slightly less likely to make them. My intent is to present an objective overview of the difficulties we face - not make us look inept. However, unwarranted confidence about decisions made is a persistent finding in this research.

Most common errors in judgement:

- Ignoring base rate - Zebras; Good response to antidepressant
- Depending too much on ease of recall of instances - air vs auto accidents
- Anchoring errors - Estimate commercial airplane deaths from auto deaths vs from train deaths 300 50000 100
- Ignoring sample size effects - 4/5 vs 20/25
- Reasoning by representativeness

Problems arise when we judge how likely something is by estimating how representative it is of some class.
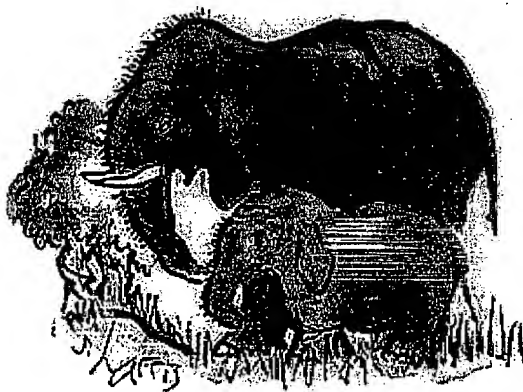
When you're young, it comes naturally, but when you get a little older, you have to rely on mnemonics. "

Suppose my schizophrenic patient comes in and seems to be deteriorating. I increase the neuroleptic a bit. At the next visit the patient is better. I am likely to see that as representative of cases in which a neuroleptic reduced symptoms. My judgement is likely to be based too much on that similarity and not enough on the probability of variation in the patient's clinical state from one visit to the next. You might not think I would make such a naive error: however, for many years psychiatrists generally used doses of neuroleptics well in excess of what was in fact needed to produce maximum benefit.

The Robust Beauty of Improper Linear Models This heading is the title of a paper by Robyn Dawes. In it Dawes reviews what is known about the predictions of experts compared to mathematical predictions.

The linear model referred to means a simple mathematical formula used to calculate an answer. An example might be a formula for deciding if a patient should receive depot neuroleptics.

Depot score = resistance rating X 4 + disorganization rating X 1 + family support rating X 2

A proper linear model has scientifically determined weighting factors for each variable (4,1 and 2 in the example). An improper linear model has no weightings or weighting factors chosen without solid scientific data.

Through studies involving experts in many fields it is clear that experts can identify the important factors for making decisions, however, they virtually always are not as good at making decisions as are simple mathematical models based on the factors the experts identify!

This points out that experts are good at knowing what is important to make decisions but like all human beings, they are poor at processing and combining probabilistic information.

A good example comes from a study of pathologists who rated biopsies of patients with Hodgkins disease. They rated several factors about the slides and made an overall rating of severity for each patient. Their severity ratings did not predict survival. However, a regression analysis using their ratings of the various factors on the slides, *was* able to predict survival. The pathologists knew what was important and could rate the factors but they could not extract maximum usefulness from it. A mathematical model did that better.

One might say that a regression analysis is very sophisticated and not usable in many real world decision making situations. Maybe you just have impressions about the weight which various facts should be given in a decision - or maybe you can't even guess at the proper weight but just think a fact is a predictor of outcome. This is not a situation for scientific despair. Many studies show that even mathematical models based on no weighting factors (You just add up the facts by counting them.) or weighting factors based on clinical hunches produce better outcomes than experts can. These are the beautiful, though somewhat professionally threatening "improper linear models" referred to above.

Sub-Optimal Treatment Algorithms

Treating patients is not a very good setting for refining treatment algorithms. In clinical situations it is *usual* for sub-optimal treatment algorithms to survive - even thrive (Einhorn, 1982). Our goal of helping patients get better often conflicts with a goal of understanding what makes our treatments succeed or fail. Decision makers generally have much more confidence in their strategies than is scientifically warranted. One reason for that is that positive results are noted much more strongly than negative outcomes - making it more difficult to discern the true pattern of cause and effect.

Clinicians cannot collect enough instances of each decision point in their treatment algorithms to assess the probability of success at each point.

Examples of sub-optimal algorithms are the long prevalent use of excessive doses of neuroleptics and the less than optimal doses on antidepressants which were recommended for preventing recurrence for depression for about two decades. Sub-optimal treatments like these occurred in part because experts lacked the knowledge of what was the best algorithm, and they persisted because clinicians could perceive that patients did better with these treatments than with no treatment - but they could not perceive that there were still better ways to the use the treatment tools at hand.

Advantages of Algorithms

An algorithm is carefully reasoned out by experts who have full command of research findings and extensive clinical experience. The experts can take the time to weed out places where faulty strategy might occur.

An algorithm attempts to most carefully translate research results into advice about specific situations. Linden (1994) has pointed out how treacherous it is to get from experimental outcome data to clinical recommendations. A research treatment protocol reveals outcomes for only a highly selective patient group; generalizability is a matter of speculation. The research usually addresses only one treatment intervention without any feedback of interim results - unlike clinical situations.

Outcome studies should regard:

Multi step process of real clinical treatment
Time
Feedback during treatment process
Preferences of patient and therapist

Linden says "it would be a major step forward to take into account the following: (a) instead of seeing treatment as a one-step event, time should be included as an important variable, and treatment be conceptualized as a process; (b) instead of only one treatment intervention, different options should be allowed in the treatment process; © not only the psychopathology, but also the motivational variables, evinced by therapist and patient, should be recognized as factors that influence the treatment process."

He believes that clinical research will be greatly aided by research which tests decision rules or "intentions" in an ongoing treatment process rather than just the usual highly controlled single intervention approach.

Linden's very high standards for what treatment algorithms should do is an appropriate transition to a discussion of computerized algorithms.

What Should a Computerized Algorithm Do?

A computerized algorithm should incorporate much greater complexity and subtlety of problem analysis and recommendations (without overwhelming the user) than a paper based algorithm.

It should be easy to update. Soon the standard will be continuous automatic updating via modem connections to the algorithm's authors.

It should handle a wide variety of cases. Help is needed most for unusual cases - not garden variety

cases, so the program must be robust.

It should address patients' preferences, fears and tolerance or intolerance of various side effects. It should take into account comorbid conditions and history of prior treatment. It should take account of the psychiatrists's preferences and experience when appropriate.

The psychiatrist and patient's preferences regarding urgency of symptom relief, risk of side effects, and therapeutic failure - such as temporary worsening of symptoms - on the way to gaining long term better outcome should be considered.

At the edges of its sphere of expertise, it should be able to "fail gracefully" - i.e. be able to give a response that is at least not bad advice. At best it should recognize when it is dealing with a case which it was not prepared to handle.

It should teach approaches that can be remembered and applied to other cases.

How to Computerize an Algorithm

Programmer and Expert Collaboration The programmer and expert need to work closely together for weeks or months to codify the expert's knowledge in well defined rules. In that process the expert often has to think out loud about how he solves particular problems and then work with the programmer to form those insights into comprehensive rules. Many attempts at this have failed because the expert was not sufficiently committed to the project and therefore would not devote sufficient time, or because the expert cannot articulate his strategies.

Considerable time has to be spent making sure all possible situations are covered by the algorithm. No condition can be left unspecified.

Computerize We are focusing today on treatment algorithms based on rules, but other approaches are possible. Computerized neural networks learn from data and outcomes you supply. The network creates its own "rules" for making decisions. There are also case based reasoning and genetic algorithm approaches. Fuzzy logic is a way to help deal with uncertainty in algorithms.

A major challenge in computerizing the algorithm is to make it easy for the user to get the information without spending much time learning the program or searching.

Test the Program Some people would insist that a program should be rigorously experimentally tested before release. In the real world that is not practical because of the costs involved. I think it is appropriate to expect a computerized algorithm to meet standards expected of other educational materials. An algorithm may be thought of as a kind of meta-analysis performed by the expert authors. It would be desirable for computerized algorithms to undergo peer review similar to that for traditional journal publications.

Distribute Distribution should be straight forward, however some interesting sociological issues will arise. Since algorithms provide more concise statements of how to treat a condition than do textbooks and ordinary journal articles, non-psychiatrist physicians, psychologists, social workers and nurses will want to use them. I think we will find people increasingly well informed and asking us questions about treatment strategy based on their examination of the treatment algorithms.

Patients and their families will begin to consult the algorithms. The Internet will greatly facilitate this because it permits an interested person to explore a treatment algorithm published on the Net anywhere in the world. It will of course be up-to-date - unlike a book or magazine article. A year ago I saw my first patient who had checked out fluoxetine on the Internet in anticipation of getting it for his depression and last week for the first time a patient requested a prescription refill over the Internet!

Computerized algorithms will tend to demystify what we do as psychopharmacologists. That will require some changes in the way we perform as healers.

What Will Convince Clinicians to Use Computerized Algorithms?

The approach should be that if you build a better mouse trap people will want to use it.

Here is a wish list of characteristics for a user friendly computerized algorithm:

Make it readily apparent that the program can deliver on the promise of aiding the clinician in caring for patients. It must not be just good enough to help a green resident and must be fully up- to-date on the latest developments - those that an average competent psychiatrist may not have had time to learn about.

Give it a high level of expertise including how to handle difficult cases.

Give it a pleasing interface - which is familiar and easy to use. Presently, Macintosh, Windows and Web page interfaces do this best. In the near future a modem connection to its authors will probably be considered essential.

Associate it with other useful programs such as a hospital information system, prescribing information or a record keeping system so that it is very convenient to access.

Make it work very quickly. Tedious data entry will not be tolerated by most clinicians.

Make sure it avoids the "Greek oracle" approach - in which an inscrutable master renders decisions without explanation (Shortliffe, 1994).

Do not make users feel they are traversing a maze. The user should be able to see where he is in the consultation as it progresses. It should allow many ways to see the expertise captured in the program. The user should be able to see the impact on the outcome when a fact is changed. Obviously, the research and clinical experience basis for recommendations needs to be spelled out.

Will Algorithms Stifle Clinicians?

More complete and more easily usable knowledge about treatment steps should be liberating. It will reduce by a little the uncertainty we deal with. It can free us to devote more attention to other elements of good treatment such as educating the patient, building rapport and gaining treatment compliance.

Even when you chose not to follow an algorithm's recommendation you will be able to do it with good knowledge of how daring your contemplated variation is and with the algorithm at hand you can probably more clearly document why you have chosen an alternative approach. If you are electronically transmitting your experience to a feed back system for that algorithm - as we will discuss next - your variation will uniquely contribute to the further development of the algorithm.

Refining Algorithms Through Networked Users Groups

Thousands of psychiatrists try treatments and get results every day but those mini-experiments contribute little to general knowledge because there is no way to bring the results together in order to see patterns.

Computerized algorithms offer the possibility of gathering outcome data on thousands of therapeutic trials without extra work from the psychiatrist. Feedback from nation-wide experience could be a major reward for psychiatrists who use computerized algorithms.

Imagine being able to use your computer connected through the Internet to a center that supports algorithms for treating schizophrenia. Using the program, you describe your patient and the program gives you a recommendation about what to do. It can be as up-to-date as of today because experts are maintaining the system. The program might tell you that the program's experience to date is 500 recommendations at this specific spot in the algorithm. Two hundred patients had very good outcomes from that recommendation; 200 more tried it but either had to stop the treatment or had a poor outcome - you could see the breakdown of this if you want; and 50 psychiatrists declined to follow the recommendation and you can see what they said about their thinking and what their outcomes were; 50 patients declined to try the treatment or were lost to follow up - a breakdown of that group would also be available.

With information like this pouring in, I can imagine experts putting up things equivalent to road signs like: "This recommendation is very solid - don't think about not following it"; or "User experience in following this recommendation is making it look doubtful. We are reassessing it".

There should not be just one system like this for schizophrenia treatment algorithms - there should be several competing ones. With hard data coming in through user feedback, the best algorithm will prove itself in time. But of course, like other complex systems, one group's algorithm might pull ahead in treating first break schizophrenics and another might excel at treating people with comorbid retardation. This could lead to hybridization, mergers, buyouts etc. among the systems - to the benefit of patients and clinicians!

Such a system seems likely to yield substantial improvement in treatment outcomes. This can be anticipated from the research which shows that, throughout medicine, improved treatment methods are slow to be adopted. An example in field of schizophrenia treatment is clozapine. Today clozapine is being given to only a modest proportion of the patients whom experts would recommend it for. The adoption of the practice recommended by experts has been slow. The psychological and economic costs of this slow adoption of new treatments is very large.

Even in situations where algorithms achieve outcome improvement of only a few percentage points, the human and economic benefits can be large. Those smaller improvements may well be at a level which a clinician treating an average patient load may not be able to detect. Suppose that by using an improved algorithm you could achieve a 2 - 3 or maybe 5 percent better treatment outcome. You would probably not be able to detect such a small change by just reviewing your patients. It *would* be detectable among a network of psychiatrists using the treatment algorithm and recording their results.

Suppose following a particular algorithm could achieve a $100/year saving for each schizophrenic patient. Maybe the saving would be achieved through less hospitalizations, or greater earnings at jobs your patients gets. If enough psychiatrists used the algorithm so 1 in ten patients in treatment got the

benefit. The cost saving nationally would be about $12.5 million! That's assuming only half of all schizophrenic patients are in treatment and one tenth of those receive the benefit of our algorithm. If all schizophrenics got the benefit the saving would be $125 million.

"How do you want it -- the crystal mumbo-jumbo or statistical probability?"

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